

#### 4.1.7.4.1 Occupational Impacts

**Industrial Hazards.** Table 4-30 lists impacts to workers from normal industrial workplace hazards for the closure phase. No workplace industrial fatalities (0.2 to 0.25) would be expected during closure. The range of impacts is due to the differences in the length of the closure period, because closure activities are similar under all operating modes.

**Table 4-30.** Impacts to workers from industrial hazards during the closure phase.<sup>a,b</sup>

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature
<i>Involved workers</i>		
Total recordable cases	320	340 - 420
Lost work day cases	150	160 - 200
Fatalities	0.15	0.16 - 0.2
<i>Noninvolved workers</i>		
Total recordable cases	51	53 - 62
Lost workday cases	25	26 - 30
Fatalities	0.045	0.047 - 0.054
<i>All workers (totals)<sup>c</sup></i>		
Total recordable cases	370	390 - 480
Lost workday cases	180	190 - 230
Fatalities	0.2	0.21 - 0.25

a. Values are rounded to two significant figures.

b. Source: Appendix F, Table F-38.

c. Totals might differ from sums of values due to rounding.

**Naturally Occurring Hazardous Material.** During closure activities there would be potential for dust to be generated (for example, during preparation and emplacement of excavated rock for backfill). The potential for dust generation, especially in the underground environment, would be less than for subsurface excavation during the construction phase and operations period. As necessary, DOE would use engineering controls and worker protection measures such as those discussed in Section 4.1.7.2.1 for the construction phase to control and minimize potential impacts to workers. Potential impacts would be very small.

**Radiological Health Impacts.** During the closure phase, subsurface workers would be exposed to radon-222 in the drift atmosphere, to external radiation from radionuclides in the drift walls, and to external radiation from the waste packages. Table 4-31 lists radiological impacts to workers for the closure phase. There is low potential for exposure of surface workers, and most of the radiation dose and potential radiological health impacts would be to subsurface workers. The maximally exposed worker would be a subsurface worker. The estimated radiological health impacts to the worker population for the 10 to 17 year closure phase would range from 0.15 to 0.28 latent cancer fatality. The range in impacts is due mainly to the differences in the length of the phase for the range of operating modes. Estimated radiological health impacts to the maximally exposed individual would range from 6.7 to 13 rem, with a corresponding probability of latent cancer fatality ranging from 0.0027 to 0.0052. The principal sources of exposure to subsurface workers would be from inhalation of radon-222 and its decay products.

#### 4.1.7.4.2 Public Health Impacts

**Naturally Occurring Hazardous Material.** Section 4.1.2.4.1 presents estimated annual average concentrations of cristobalite during the closure phase at the land withdrawal boundary, where members of the public could be exposed. There would be no subsurface excavation during the closure phase, so cristobalite concentrations would be less than for earlier phases. Annual average concentrations of about 0.012 to 0.013 microgram per cubic meter were estimated for the operating modes, and health impacts to

**Table 4-31.** Radiation dose and radiological health impacts to workers during closure phase.<sup>a,b,c</sup>

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature
<i>Maximally exposed worker<sup>d</sup></i>		
<i>Dose, rem</i>		
Involved	6.7	7.9 - 13
Noninvolved	0.36	0.40 - 0.61
<i>Probability of latent cancer fatality</i>		
Involved	0.0027	0.0032 - 0.0052
Noninvolved	0.00014	0.00016 - 0.00024
<i>Worker population</i>		
<i>Collective dose (person-rem)</i>		
Involved	430	480 - 740
Noninvolved	16	18 - 28
Total <sup>e</sup>	450	500 - 770
<i>Number of latent cancer fatalities</i>		
Involved	0.17	0.19 - 0.30
Noninvolved	0.0064	0.0072 - 0.011
<b>Total<sup>e</sup></b>	<b>0.18</b>	<b>0.2 - 0.31</b>

a. Numbers are rounded to two significant figures.

b. Source: Appendix F, Table F-39.

c. Closure phase would last 10 to 17 years.

d. The maximally exposed individual would be a subsurface worker.

e. Totals might differ from sums of values due to rounding.

the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure. Potential impacts would be very small.

**Radiological Health Impacts.** Potential radiation-related health impacts to the public from closure activities would result from exposure to radon-222 and its decay products released in the subsurface exhaust ventilation air. Section 4.1.2.4.2 presents estimates of dose to the public for the closure phase. Table 4-32 lists the estimated dose and radiological health impacts.

**Table 4-32.** Radiation dose and radiological health impacts to public for the closure phase.<sup>a,b,c,d</sup>

Dose and health impact	Operating mode			
	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
	Entire phase		Maximum annual	
<i>Maximally exposed individual<sup>e</sup></i>				
Dose (millirem)	3	4.3 - 9.4	0.4	0.57 - 0.87
Latent cancer fatality probability	$1.5 \times 10^{-6}$	$2.2 - 4.7 \times 10^{-6}$	$2.0 \times 10^{-7}$	$2.8 - 4.3 \times 10^{-7}$
<i>Exposed 80-km population<sup>f</sup></i>				
Collective dose (person-rem)	57	83 - 180	7.4	10 - 16
Number of latent cancer fatality	0.028	0.041 - 0.090	0.0037	0.0052 - 0.0081

a. Numbers are rounded to two significant figures.

b. Source: Table 4-7.

c. All dose would be from naturally occurring radon-222 and decay products.

d. The closure phase would last from 10 to 17 years.

e. Individual located at the southern boundary of the land withdrawal area.

f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

Potential radiological health impacts would be small. The probability of a latent cancer fatality occurring in the maximally exposed individual would be 0.0000047 or less. The number of latent cancer fatalities

estimated to occur in the exposed population would range from 0.028 to 0.090. Differences in potential impacts are due mainly to differences in the length of the closure phase.

#### 4.1.7.5 Total Impacts to Occupational and Public Health and Safety for All Phases

This section presents estimates of the total human health and safety impacts to workers and members of the public from proposed activities at the Yucca Mountain repository. It describes the total impacts from activities during the construction, operation and monitoring, and closure phases to workers from industrial hazards and radiation exposure, and to members of the public from radiation exposure.

Among other operating factors, total project impacts would depend on the duration of the project. The higher-temperature operating mode would last 115 years, while the lower-temperature operating mode would last from 171 to 341 years. These time periods include a 5-year construction phase and variable time periods for the operation and monitoring phase (100 to 324 years) and closure phase (10 to 17 years), as discussed in the previous sections. In general, the highest potential health and safety impacts would occur during the operation and monitoring phase.

##### 4.1.7.5.1 Total Impacts to Workers from Industrial Hazards for All Phases

Total impacts to workers from industrial hazards for the entire project are shown in Table 4-33. The estimated number of workplace fatalities would range from 2.0 for the higher-temperature operating mode to 3.3 for the upper end of the lower-temperature operating mode.

**Table 4-33.** Total impacts to workers from industrial hazards for all phases.<sup>a</sup>

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature <sup>b</sup>
<i>Involved workers</i>		
Total recordable cases	2,200	2,500 - 3,300
Lost work day cases	1,000	1,200 - 1,500
Fatalities	1.5	1.8 - 2.6
<i>Noninvolved workers</i>		
Total recordable cases	460	500 - 720
Lost workday cases	230	250 - 350
Fatalities	0.45	0.48 - 0.68
<i>All workers (totals<sup>c,d</sup>)</i>		
Total recordable cases	2,700	3,000 - 4,000
Lost workday cases	1,300	1,500 - 1,900
Fatalities	2.0	2.3 - 3.3

a. Numbers are rounded to two significant figures.

b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

c. Source: Tables 4-21, 4-24, 4-27, and 4-30.

d. Totals might differ from sums of values due to rounding.

##### 4.1.7.5.2 Total Radiological Health Impacts to Workers for All Phases

Total radiation dose and radiological health impacts to workers for the entire project (all phases) are listed in Table 4-34. Dose and impact for the maximally exposed individual worker are listed for a 50-year working lifetime. The collective dose to the worker population and potential radiological health impacts are shown for the entire project duration, ranging from 115 years for the higher-temperature operating mode up to 341 years for the lower-temperature operating mode.

**Table 4-34.** Total radiation dose and radiological health impacts to workers for all phases.<sup>a,b</sup>

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature
<i>Maximally exposed worker<sup>d</sup></i>		
<i>Dose, rem</i>		
Involved	18	18 - 30
Noninvolved	1.8	1.8
<i>Probability of latent cancer fatality</i>		
Involved	0.0072	0.0072 - 0.012
Noninvolved	0.00072	0.00072
<i>Worker population</i>		
<i>Collective dose (person-rem)</i>		
Involved	9,700	11,000 - 17,000
Noninvolved	240	280 - 360
<b>Total<sup>e</sup></b>	<b>10,000</b>	<b>11,000 - 17,000</b>
<i>Number of latent cancer fatalities</i>		
Involved	3.9	4.4 - 6.8
Noninvolved	0.092	0.11 - 0.14
<b>Total<sup>e</sup></b>	<b>4.0</b>	<b>4.4 - 6.8</b>

a. Numbers are rounded to two significant figures.

b. Source: Tables 4-22, 4-25, 4-28, and 4-31 for the construction phase, operations period, monitoring period, and closure phase, respectively.

c. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

d. For a 50-year working lifetime.

e. Totals might differ from sums of values due to rounding.

The maximally exposed worker is a subsurface worker whose 50-year working lifetime would span the 50-year operations period needed for aging of spent nuclear fuel. This worker would be a locomotive operator or brakeman who is involved in the transport and emplacement of the spent nuclear fuel. Receiving an estimated radiation dose of about 30 rem, the probability of incurring a latent cancer fatality would be about 0.012 for this individual.

The total estimated number of latent cancer fatalities that could occur in the repository workforce from the radiation dose received over the entire project would be about 4 for the 115 years of exposure during the higher-temperature operating mode. The number of latent cancer fatalities would range from 4.4 to 6.8, for the 171 to 341 years, respectively, of the lower-temperature operating mode. About 80 percent of the dose and associated risk of latent cancer fatality would occur during the operations period for surface and subsurface workforce. The principal source of exposure would be external radiation from spent nuclear fuel handling in surface facilities and waste package emplacement in the subsurface facility. Inhalation of radon-222 and its decay products by subsurface workers would account for 25 percent of the total worker dose. Ambient radiation exposure to subsurface workers would account for about 10 percent of the total worker dose.

#### 4.1.7.5.3 Total Radiological Health Impacts to the Public for All Phases

The estimated radiation dose and radiological health impacts to the public for the entire project—which includes the period prior to final repository closure—are listed in Table 4-35. Dose and the potential radiological impact are listed for the offsite maximally exposed individual, assumed to reside continuously for a 70-year lifetime at the southern boundary of the land withdrawal area. This individual would have a probability of latent cancer fatality of 0.000031 or less from exposure to radionuclides released from the repository during the preclosure period. More than 99.9 percent of the potential health impact would be from naturally occurring radon-222 and its decay products released in exhaust

**Table 4-35.** Total dose and radiological impacts to the public for all phases.<sup>a,b,c,d</sup>

Dose and health impact	Operating mode			
	Higher-temperature	Lower-temperature <sup>e</sup>	Higher-temperature	Lower-temperature <sup>e</sup>
	Entire project		Maximum annual	
Maximally exposed individual <sup>f</sup>				
Dose (millirem)	31	44 - 62	0.73	1 - 1.3
Latent cancer fatality probability	$1.6 \times 10^{-5}$	$2.2 - 3.1 \times 10^{-5}$	$3.7 \times 10^{-7}$	$5.2 - 6.7 \times 10^{-7}$
Exposed 80-km population <sup>g</sup>				
Collective dose (person-rem)	930	1,900 - 3,900	14	20 - 26
Number of latent cancer fatality	0.46	0.97 - 2	0.0071	0.010 - 0.013

a. Numbers are rounded to two significant figures.

b. Source: Table 4-8, Section 4.1.2.5.

c. Greater than 99.9 percent of dose would be from naturally occurring radon-222 and decay products.

d. Project would last from 115 to 341 years.

e. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

f. Individual located at the southern boundary of the land withdrawal area for a 70-year lifetime including all of the operations period (24 or 50 years) with the remainder during the monitoring period.

g. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

ventilation air. The highest annual radiation dose would range from 0.73 to 1.3 millirem, less than 1 percent of the annual 200-millirem dose to members of the public in Amargosa Valley from ambient levels of naturally occurring radon-222 and its decay products (Chapter 3, Section 3.1.8.2).

The collective or population dose and associated radiological health impacts are listed in Table 4-35 for the population within 80 kilometers (50 miles) for the entire project duration, ranging from 115 years for the higher-temperature operating mode up to 341 years for the lower-temperature operating mode. An estimated 0.46 latent cancer fatality would occur for the higher-temperature operating mode, and from 0.97 to 2.0 latent cancer fatalities would occur for the lower-temperature operating mode. Statistics published by the Centers for Disease Control indicate that during 1998, 24 percent of all deaths in the State of Nevada were attributable to cancer of some type and cause (DIRS 153066-Murphy 2000, p. 8). Assuming this rate would remain unchanged for the estimated population (in 2035) of about 76,000 within 80 kilometers (50 miles) of the Yucca Mountain site, about 18,000 members of this population would be expected to die from cancer-related causes. During the time the project was active, the number of cancer deaths unrelated to the project would range from about 30,000 to 89,000 in the general population. Estimated project-related impacts (0.46 to 2 latent cancer fatalities) would be a very small increase (0.007 percent or less) over this baseline. The potential human health impacts of long-term repository performance are discussed in Chapter 5.

#### 4.1.8 ACCIDENT SCENARIO IMPACTS

This section describes the impacts from potential accident scenarios from performance confirmation, construction, operation and monitoring, and closure activities. The analysis is separated into radiological accidents (Section 4.1.8.1) and nonradiological accidents (Section 4.1.8.2). The analysis of radiological accident consequences used the MACCS2 computer code (DIRS 103168-Chanin and Young 1998, all). The receptors would be (1) the *maximally exposed individual*, defined as a hypothetical member of the public at the point on the land withdrawal boundary that would receive the largest dose from the assumed accident scenario, (2) the *involved worker*, a worker who would be handling the spent nuclear fuel or high-level radioactive waste when the accident occurred, (3) the *noninvolved worker*, a worker near the accident but not involved in handling the material, and (4) members of the public who reside within



approximately 80 kilometers (50 miles) of the proposed repository. All analysis method details are provided in Appendix H.

The impacts to offsite individuals from repository accidents would be small, with calculated doses of 0.038 rem or less to the maximally exposed offsite individual. Doses to a maximally exposed noninvolved worker would be higher than those to offsite individuals, up to 16 rem. Some of the very unlikely accidents would be expected to severely injure or kill involved workers.

#### 4.1.8.1 Radiological Accidents

The first step in the radiological accident analysis was to examine the initiating events that could lead to facility accidents. These events could be external or internal. External initiators originate outside a facility and affect its ability to confine radioactive material. They include human-caused events such as aircraft crashes, external fires and explosions, and natural phenomena such as seismic disturbances and extreme weather conditions. Internal initiators occur inside a facility and include human errors, equipment failures, or combinations of the two. DOE analyzed initiating events applicable to repository operations to define subsequent sequences of events that could result in releases of radioactive material or radiation exposure. For each event in these accident sequences, the analysis estimated and combined probabilities to produce an estimate of the overall accident probability for the sequence. In addition, the analysis used bounding (plausible upper limit) accident scenarios to represent the impacts from groups of similar accidents. Finally, it evaluated the consequences of the postulated accident scenarios by estimating the potential radiation dose and radiological impacts.

##### ACCIDENT TYPES

**Radiological accidents** are unplanned events that could result in exposure of nearby humans to direct radiation or to radioactive material that would be ingested or inhaled.

**Nonradiological accidents** are unplanned events that could result in exposure of nearby humans to hazardous or toxic materials released to the environment as a result of the accident.

The analysis used accident analyses previously performed by others for repository operation whenever possible to identify potential accidents. DOE reviewed these analyses for their applicability to the repository before using them (see Appendix H). The spectrum of accident scenarios evaluated in the analysis is based on the current conceptual design of the facility. Final facility design details are not available; the final designs could affect both the frequency and consequences of postulated accidents. For areas without final facility design criteria, DOE made assumptions to ensure that the analysis did not underestimate impacts.

The radionuclide *source term* for various accident scenarios could involve several different types of radioactive materials. These would include commercial spent nuclear fuel from both boiling- and pressurized-water commercial reactors (see Appendix A, Section A.2.1), DOE spent nuclear fuel (see Appendix A, Section A.2.2), DOE high-level radioactive waste incorporated in a glass matrix (see Appendix A, Section A.2.3), and weapons-grade plutonium either immobilized in high-level radioactive waste glass matrix or as mixed-oxide fuel (see Appendix A, Section A.2.4). Appendix A contains information on the radionuclide inventories in these materials. The analysis also examined accident scenarios involving the release of low-level waste generated and handled at the repository, primarily in the Waste Treatment Building.

The analysis used the radionuclide inventories from Appendix A for a representative fuel element to estimate the material that could be involved in an accident. It used the MACCS2 computer program, developed under the guidance of the Nuclear Regulatory Commission, to estimate potential radiation

doses to exposed individuals (onsite and offsite) and population groups from postulated accidental releases of radionuclides. Appendix H contains additional information on the MACCS2 program and the models and assumptions incorporated in it.

The analysis considered radiological consequences of the postulated accidents for the following individuals and populations:

- **Involved worker.** A facility worker directly involved in activities at the location where the postulated accident could occur
- **Maximally exposed noninvolved worker (collocated worker).** A worker not directly involved with material unloading, transfer, and emplacement activities, assumed to be 100 meters (330 feet) downwind of the facility where the release occurs
- **Maximally exposed offsite individual.** A hypothetical member of the public at the nearest point to the facility at the site boundary. The analysis determined that the land withdrawal boundary location with the highest potential exposure from an accidental release of radioactive material would be either about 8 or 11 kilometers (5 or 7 miles) from the accident location (at the western boundary of the land withdrawal area analyzed). The maximally exposed individual for a single-point release of material is different than those for a continuous release (see Section 4.1.2) because the maximally exposed individual could not be present continuously at the western boundary because this is government-owned land.
- **Offsite population.** Members of the public within 80 kilometers (50 miles) of the repository site (see Chapter 3)

Ten accident scenarios were analyzed in detail. These scenarios bound the consequences of credible accidents at the repository. They include accidents in the Cask/Handling Area, the Canister Transfer System, the Assembly Transfer System, the Disposal Container Handling Area, and the Waste Treatment Building. The scenarios consider drops and collisions involving shipping casks, bare fuel assemblies, low-level radioactive waste drums, and the waste package transporter.

The 10 accident scenarios in Tables 4-36 and 4-37 replace the 16 accident scenarios analyzed in the Draft EIS. The number of scenarios was reduced because several accidents analyzed in the Draft EIS were found to be no longer credible based on design changes, revised system-failure probabilities, and new information on the capability of DOE canisters and transportation casks to withstand drops. Details of these changes are in Appendix H, Section H.2.1.1.

Table 4-36 lists the results of the radiological accident consequence analysis under median, or 50th-percentile meteorological conditions. Table 4-37 lists similar information based on unfavorable meteorological conditions (95th-percentile, or those conditions that would not be exceeded more than 5 percent of the time) that tend to maximize potential radiological impacts. Impacts to the noninvolved worker would result from the inhalation of airborne radionuclides and external radiation from the passing plume. Impacts to the maximally exposed offsite individual and the offsite population would result from these exposure pathways and from long-term external exposure to radionuclides deposited on soil during plume passage, subsequent ingestion of radionuclides in locally grown food, and inhalation of resuspended particulates. The analysis did not consider interdiction by DOE or other government agencies to limit long-term radiation doses because none of these doses would be above the Environmental Protection Agency's Protective Action Guides. Interdiction would be likely to occur if the calculated accident doses exceeded these guides.

**Table 4-36.** Radiological consequences of repository operations accident scenarios for median (50th-percentile) meteorological conditions.

Accident scenario <sup>a,b</sup>	Frequency (per year) <sup>a</sup>	Maximally exposed offsite individual <sup>c</sup>		Population		Noninvolved worker		Involved worker	
		Dose (rem)	LCFi <sup>d</sup>	Dose (person-rem)	LCFp <sup>d</sup>	Dose (rem)	LCFi	Dose (rem)	LCFi
1. Basket drop onto another basket in pool (PWR fuel)	0.04	$8.2 \times 10^{-7}$	$4.1 \times 10^{-10}$	$4.9 \times 10^{-4}$	$2.4 \times 10^{-7}$	$3.6 \times 10^{-4}$	$1.4 \times 10^{-7}$	(e)	(e)
2. Basket drop onto another basket in dryer (PWR fuel)	0.04	$8.7 \times 10^{-6}$	$4.4 \times 10^{-9}$	$8.9 \times 10^{-4}$	$4.4 \times 10^{-7}$	$4.5 \times 10^{-3}$	$1.8 \times 10^{-6}$	(e)	(e)
3. Drop of transfer basket onto another basket in dryer (BWR fuel)	$7.4 \times 10^{-3}$	$6.4 \times 10^{-6}$	$3.2 \times 10^{-9}$	$6.0 \times 10^{-4}$	$3.0 \times 10^{-7}$	$3.1 \times 10^{-5}$	$1.2 \times 10^{-8}$	(e)	(e)
4. Unsealed DC drop and slapdown in cell (PWR fuel)	$8.4 \times 10^{-3}$	$2.6 \times 10^{-5}$	$1.3 \times 10^{-8}$	$2.5 \times 10^{-3}$	$1.2 \times 10^{-6}$	$1.3 \times 10^{-2}$	$5.2 \times 10^{-6}$	(e)	(e)
5. Unsealed shipping cask drop in CPP (PWR fuel)	$8.7 \times 10^{-3}$	$3.4 \times 10^{-5}$	$1.8 \times 10^{-8}$	$3.0 \times 10^{-3}$	$1.5 \times 10^{-6}$	$1.8 \times 10^{-2}$	$7.4 \times 10^{-6}$	(e)	(e)
6. Unsealed shipping cask drop in pool (PWR fuel)	$8.7 \times 10^{-3}$	$2.5 \times 10^{-6}$	$1.3 \times 10^{-9}$	$1.5 \times 10^{-3}$	$7.3 \times 10^{-7}$	$1.0 \times 10^{-3}$	$4.1 \times 10^{-7}$	(e)	(e)
7. Transporter runaway and derailment (PWR fuel)	$1.2 \times 10^{-7}$	$1.0 \times 10^{-2}$	$5.0 \times 10^{-6}$	0.14	$7.3 \times 10^{-5}$	3.2	$1.3 \times 10^{-3}$	(f)	(f)
8. Beyond design basis earthquake in WHB (PWR fuel)	$2.0 \times 10^{-5}$	$1.2 \times 10^{-2}$	$6.0 \times 10^{-6}$	0.63	$3.2 \times 10^{-4}$	4.9	$2.0 \times 10^{-3}$	(f)	(f)
9. Earthquake with fire in WTB	$2.0 \times 10^{-5}$	$1.6 \times 10^{-5}$	$8.0 \times 10^{-9}$	$8.9 \times 10^{-4}$	$4.4 \times 10^{-7}$	$8.2 \times 10^{-4}$	$3.3 \times 10^{-7}$	(f)	(f)
10. Low level waste drum rupture in WTB	0.59	$5.7 \times 10^{-10}$	$2.9 \times 10^{-13}$	$3.0 \times 10^{-8}$	$1.4 \times 10^{-11}$	$2.5 \times 10^{-8}$	$1.0 \times 10^{-11}$	$8.8 \times 10^{-5}$	$3.5 \times 10^{-8}$

a. Source: Appendix H

b. DC = Disposal Container, CPP = Cask Preparation Pit, PWR = Pressurized Water Reactor, BWR = Boiling Water Reactor, WHB = Waste Handling Building, WTB = Waste Treatment Building.

c. Assumed to be at the nearest land withdrawal boundary, which would be 11 kilometers (7 miles) for all accident scenarios except 7. For these accidents, the distance would be 8 kilometers (5 miles).

d. LCFi is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the estimated number of cancers in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as discussed in Appendix F, Section F.1.1.5.

e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident because operations are done remotely. Thus, involved worker impacts were not evaluated.

f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on staffing projections (DIRS 104718-CRWMS M&O 1998, pp. 17 and 18).

The *maximum reasonably foreseeable accident scenario* (earthquake, Table 4-37, number 8) for the 95-percent weather conditions would result in an estimated 0.011 additional latent cancer fatality for the same affected population. The more conservative summation of all foreseeable accidents in Table 4-37 results in less than 0.02 additional latent cancer fatality for the exposed population. Thus, the estimated number of latent cancer fatalities for the offsite individuals from accidents would be very small.

The results described in this section assumed that all commercial spent nuclear fuel would arrive at the repository either uncanistered or in canisters not suitable for disposal. In this base case scenario, all of the fuel would have to be handled as bare fuel assemblies in the Waste Handling Building and placed in disposal containers for disposal, as described above. The base case scenario, which assumes that all fuel would have to be handled as bare fuel assemblies, provides a bounding assessment of accident impacts compared to canistered scenarios. The uncanistered fuel, as indicated in Tables 4-36 and 4-37, represents the more meaningful accident risk because of the additional handling operations required and the higher impacts associated with accidents involving bare assemblies. As a consequence, the base case evaluated in this section provides a bounding assessment of accident impacts in relation to the packaging scenarios.



**Table 4-37.** Radiological consequences of repository operations accident scenarios for unfavorable (95th-percentile) meteorological conditions.

Accident scenario <sup>a,b</sup>	Frequency (per year) <sup>b</sup>	Maximally exposed offsite individual <sup>c</sup>		Population		Noninvolved worker		Involved worker	
		Dose (rem)	LCFi <sup>d</sup>	Dose (person-rem)	LCFp <sup>d</sup>	Dose (rem)	LCFi	Dose (rem)	LCFi
1. Basket drop onto another basket in pool (PWR fuel)	0.04	$3.3 \times 10^{-6}$	$1.7 \times 10^{-9}$	$4.0 \times 10^{-2}$	$2.0 \times 10^{-5}$	$2.0 \times 10^{-3}$	$8.0 \times 10^{-7}$	(e)	(e)
2. Basket drop onto another basket in dryer (PWR fuel)	0.04	$3.2 \times 10^{-5}$	$1.6 \times 10^{-8}$	$4.7 \times 10^{-2}$	$2.3 \times 10^{-5}$	$2.3 \times 10^{-2}$	$9.2 \times 10^{-6}$	(e)	(e)
3. Drop of transfer basket onto another basket in dryer (BWR fuel)	$7.4 \times 10^{-3}$	$2.3 \times 10^{-5}$	$1.2 \times 10^{-8}$	$3.0 \times 10^{-2}$	$1.4 \times 10^{-5}$	$1.6 \times 10^{-4}$	$6.4 \times 10^{-8}$	(e)	(e)
4. Unsealed DC drop and slapdown in cell (PWR fuel)	$8.4 \times 10^{-3}$	$9.3 \times 10^{-5}$	$4.7 \times 10^{-8}$	0.12	$6.2 \times 10^{-5}$	$7.4 \times 10^{-2}$	$3.0 \times 10^{-5}$	(e)	(e)
5. Unsealed shipping cask drop in CPP (PWR fuel)	$8.7 \times 10^{-3}$	$1.1 \times 10^{-4}$	$5.5 \times 10^{-8}$	0.14	$7.2 \times 10^{-5}$	0.10	$4.1 \times 10^{-5}$	(e)	(e)
6. Unsealed shipping cask drop in pool (PWR fuel)	$8.7 \times 10^{-3}$	$1.0 \times 10^{-5}$	$5.0 \times 10^{-9}$	0.12	$6.0 \times 10^{-5}$	$6.0 \times 10^{-3}$	$2.4 \times 10^{-6}$	(e)	(e)
7. Transporter runaway and derailment (PWR fuel)	$1.2 \times 10^{-7}$	$3.8 \times 10^{-2}$	$1.9 \times 10^{-5}$	4.3	$2.2 \times 10^{-3}$	16	$6.4 \times 10^{-3}$	(e)	(e)
8. Beyond design basis earthquake in WHB (PWR fuel)	$2.0 \times 10^{-5}$	$3.8 \times 10^{-2}$	$1.9 \times 10^{-5}$	21	$1.1 \times 10^{-2}$	25	$9.8 \times 10^{-3}$	(f)	(f)
9. Earthquake with fire in WTB	$2.0 \times 10^{-5}$	$5.4 \times 10^{-5}$	$2.7 \times 10^{-8}$	$3.1 \times 10^{-2}$	$1.5 \times 10^{-5}$	$6.5 \times 10^{-3}$	$2.6 \times 10^{-6}$	(f)	(f)
10. Low level waste drum rupture in WTB	0.59	$1.6 \times 10^{-9}$	$8.0 \times 10^{-13}$	$1.1 \times 10^{-6}$	$5.3 \times 10^{-10}$	$2.0 \times 10^{-7}$	$8.0 \times 10^{-11}$	$8.8 \times 10^{-5}$	$3.5 \times 10^{-8}$

a. Source: Appendix H.

b. DC = Disposal Container, CPP = Cask Preparation Pit, PWR = Pressurized Water Reactor, BWR = Boiling Water Reactor, WHB = Waste Handling Building, WTB = Waste Treatment Building.

c. Assumed to be at the nearest land withdrawal boundary, which would be 11 kilometers (7 miles) for all accidents except 7. For these accidents, the distance would be 8 kilometers (5 miles).

d. LCFi is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the estimated number of cancers in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as discussed in Section F.1.1.5.

e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident because operations are done remotely. Thus, involved worker impacts were not evaluated.

f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on staffing projections (DIRS 104718-CRWMS M&O 1998, pp. 17 and 18).

The analysis also evaluated the probability of an aircraft crash onto storage modules which could be used in a surface aging facility. A military aircraft crash onto a storage module was found to be a reasonably foreseeable event; however, the analysis determined that the aircraft would not penetrate the storage module and no release would occur. A crash of a commercial jet airliner into the surface aging facility was also evaluated, even though the probability of such an event is not reasonably foreseeable. The results of the evaluation also indicate no penetration of the storage modules and no release of radiological materials. Details are provided in Appendix H, Section H.2.1.3.

In addition to the reasonably foreseeable accidents summarized in this section, DOE evaluated a hypothetical beyond-credible event (annual probability less than 1 in 10 million) involving an aircraft crash into the repository (see Appendix H, Section H.2.1.5.1). It was determined that an aircraft crash into the Waste Handling Building would result in the maximum estimated consequences. DOE assumed that evacuation of potentially exposed individuals would occur one day after the event, and also that contaminated food and water would be monitored and confiscated if necessary. The dose to the maximally exposed individual was estimated to be 4.5 rem, with a 0.0023 probability of a latent cancer fatality. The dose to the population within 80 kilometers (50 miles) was estimated to be 78 person-rem, with 0.039 latent cancer fatality resulting from this dose.